UNITED
NATIONS

A

General Assembly

Distr.
GENERAL

A/AC.105/657
13 December 1996

ORIGINAL: ENGLISH

COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

REPORT ON THE SIXTH UNITED NATIONS/EUROPEAN SPACE AGENCY WORKSHOP ON BASIC SPACE SCIENCE: GROUND-BASED AND SPACE-BORNE ASTRONOMY, HOSTED BY THE GERMAN SPACE AGENCY, ON BEHALF OF THE GOVERNMENT OF GERMANY, AT THE MAX-PLANCK-INSTITUTE FOR RADIOASTRONOMY

PRINCETON UNIVERSITY LIBRARY

(Bonn, Germany, 9-13 September 1996)

CONTENTS

		Paragraphs	*Page*
INTRODUCTION		1-10	2
A.	Background and objectives	1-5	2
B.	Organization and programme of the Workshop	6-10	2
I.	OBSERVATIONS AND RECOMMENDATIONS	11-28	3
A.	Basic space science, world space observatory and the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space	11-16	3
B.	Centres for space science and technology education: regional cooperation in basic space science	17-18	5
C.	Basic space science in Africa	19-20	5
D.	International network of astronomical observatories	21-22	6
E.	Continuation of the workshops on basic space science	23-28	6
II.	FOLLOW-UP PROJECTS OF THE UNITED NATIONS/EUROPEAN SPACE AGENCY WORKSHOPS ON BASIC SPACE SCIENCE HELD FROM 1991 TO 1996	29-48	7
A.	Asia and the Pacific: astronomical telescope facility in Sri Lanka	29-37	7
B.	South America: Galactic Emission Maps project in Colombia	38-40	8

V.96-88288T

		Paragraphs	*Page*
C.	Central America: astronomical Observatory in Honduras	41	8
D.	Western Asia: Kottamia Observatory in Egypt	42	9
E.	Contribution of Egypt to the United States/Russian Federation Mars mission scheduled for 2001	43-48	9
III.	SELECTED PROJECTS	49-74	10
A.	Oriental Robotic Telescope network	49-60	10
B.	Pierre Auger project sponsored by the United Nations Educational, Scientific and Cultural Organization	61-66	11
C.	Education and research using small astronomical telescopes	67-71	12
D.	Developing astronomy and space science worldwide	72-74	13

INTRODUCTION

A. Background and objectives

1. The General Assembly, in its resolution 37/90 of 10 December 1982, decided, upon the recommendation of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), that the United Nations Programme on Space Applications, *inter alia*, should promote greater cooperation in space science and technology between developed and developing countries as well as among developing countries.

2. The Committee on the Peaceful Uses of Outer Space at its thirty-eighth session, held in June 1995, endorsed the activities proposed for the United Nations Programme on Space Applications for 1996, as recommended by the Scientific and Technical Subcommittee at its thirty-second session. Subsequently, in its resolution 50/27 of 6 December 1995, the General Assembly endorsed the activities of the Programme for 1996.

3. In response to General Assembly resolution 50/27 and in accordance with the recommendations of UNISPACE 82, the Sixth United Nations/European Space Agency Workshop on Basic Space Science: Ground-based and Space-borne Astronomy, was organized within the framework of the activities of the Programme for 1996, particularly for the benefit of developing countries and eastern European countries.

4. The Workshop was organized jointly by the Office for Outer Space Affairs, the European Space Agency (ESA), the German Space Agency (DARA), the Max-Planck-Institute for Radioastronomy at Bonn, and The Planetary Society (TPS).

5. The objective of the Workshop was to assess the achievements of the United Nations/ESA workshops on basic space science held from 1991 to 1996, by the following means: the review of activities of the Committee in the field of basic space science; status reports on the follow-up projects that emanated from the series of workshops; scientific presentations on cosmic-rays, photon, neutrino and gravitational-wave astronomy; scientific presentations on planetary exploration; working-group sessions to address immediate problems and projects; and selected presentations on important topics for developing countries and eastern European countries.

B. Organization and programme of the Workshop

6. The Workshop was held at the Max-Planck-Institute for Radioastronomy, Bonn, Germany, from 9 to 13 September 1996. The Workshop continued a series of annual United Nations/ESA workshops on basic

space science, which had been held in India in 1991 and in Sri Lanka in 1995 for the region of Asia and the Pacific (A/AC.105/489 and A/AC.105/640), in Costa Rica and Colombia in 1992 for the region of Latin America and the Caribbean (A/AC.105/530), in Nigeria in 1993 for Africa (A/AC.105/560/Add.1) and in Egypt in 1994 for western Asia (A/AC.105/580).

7. The Workshop was attended by 120 astronomers and space scientists from the following 34 countries: Austria, Bolivia, Bulgaria, Canada, Cuba, Czech Republic, Egypt, France, Germany, Honduras, Hungary, India, Italy, Japan, Jordan, Kazakstan, Libyan Arab Jamahiriya, Morocco, Netherlands, Nigeria, Pakistan, Philippines, Poland, Russian Federation, Slovakia, South Africa, Spain, Sri Lanka, Sweden, Tunisia, Turkey, United Kingdom of Great Britain and Northern Ireland, United States of America and Viet Nam. The United Nations, DARA and ESA provided financial support to defray the cost of air travel and living expenses of 30 participants from developing countries and eastern European countries. The expenses of other participants were defrayed by the following co-organizers of the Workshop: the Austrian Space Agency, the *Centre national d'études spatiales* (French National Centre for Space Studies), the International Centre for Theoretical Physics, the Institute for Space and Astronautical Sciences of Japan, the National Aeronautics and Space Administration (NASA) of the United States and TPS. Facilities, equipment and local transportation were provided by the German Space Agency.

8. The programme of the Workshop was developed jointly by the Office for Outer Space Affairs, DARA, ESA, the Max-Planck-Institute for Radioastronomy and the University of Bonn.

9. Opening addresses were made by M. Fluegger, on behalf of the Ministry of Foreign Affairs of Germany; J.-B. Mennicken, on behalf of DARA; H. J. Haubold, on behalf of the Office for Outer Space Affairs; A. Pedersen, on behalf of ESA; P. G. Mezger, Max-Planck-Institute for Radioastronomy; L. Friedman, on behalf of TPS; and M. Huber, University of Bonn.

10. The present report, which covers the background, objectives and organization of the Workshop, as well as giving a summary of observations, recommendations and selected presentations made at the Workshop, was prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. The participants reported on the information acquired and the work conducted at the Workshop to the appropriate authorities of their Governments, universities, observatories and research institutions. The proceedings of the Workshop will be published in cooperation with the Max-Planck-Institute for Radioastronomy.

I. OBSERVATIONS AND RECOMMENDATIONS

A. Basic space science, world space observatory and the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space

11. In view of the progress made by developing countries in all regions to promote awareness of the importance of education in basic space science, particularly by installing small telescope facilities and their use in educational and research activities, plans should be devised to enhance the participation of developing countries in more advanced research at an early stage. A very effective means of achieving that goal would be for all space agencies actively to promote participation in future projects.

12. Coordination of such efforts by the major spacefaring nations would be a very important stimulus for the development process, and would enhance the capability of all countries to benefit through participation in space-related activities. It is therefore recommended that the United Nations should explore such action in the context of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space

(UNISPACE III).* This could be done either in association with the proposed World Space Observatory (A/AC.105/640), or through projects to develop instrumentation independently or pursuant to plans for future space missions. A mission related to basic space science as a joint effort between scientists in all countries of the world would provide an impressive illustration of the advantages and importance of international cooperation in such activities. Which scientific activities would be suitable for such an effort should be evaluated in future workshops on basic space science.

13. The importance of cooperation can be seen directly in:

(a) The increase in hands-on experience acquired by non-spacefaring nations;

(b) The development of effective mechanisms for collaboration between those who are involved in space exploration and those who have not yet participated;

(c) The achievement of a high educational impact and the promotion of national awareness of the benefits and importance of participation in space activities, which would be built up through the operation of a World Space Observatory;

(d) The creation of employment in basic space science, which is an essential part of the development process.

14. The above-mentioned developments sprang from a recognition that the beginning of the third millennium presents a unique opportunity to highlight the global nature of basic space science and to stimulate international collaboration in this field. UNISPACE III provides an occasion to define new worldwide action in basic space science to enhance the participation of States that are currently not involved in such activities.

15. The accelerated development needed to bridge the gap in technological development requires all States to use an original approach in generating activities associated with basic space science. The implementation of such activities should be possible, given the necessary infrastructures for the development process.

16. The use of modern communication, administrative and industrial technologies should be considered an essential part of the overall effort. Almost every activity and project discussed in the present report would be enhanced by the increased access of scientists worldwide to the Internet. In the current phase, the global nature of basic space science can supply an important stimulus to the establishment of worldwide accessible facilities for basic space science, such as:

(a) The already available Global Navigation and Positioning System for geoplanetary studies requiring data acquisition on a worldwide scale to ensure progress in the understanding of geophysical phenomena;

(b) Centres for sharing data already collected by the major space agencies and open, in general, to the public. Access to such collections of primary data continues to be a very powerful tool for participation in advanced research, for creating local support for basic space science, and for promoting the education process;

(c) A World Space Observatory for those windows that remain inaccessible from the ground;

(d) Early and direct participation in further exploration of the nature of the solar environment and the planetary system.

---

*To be convened in 1999 or 2000 as a special session of the Committee on the Peaceful Uses of Outer Space open to all Member States of the United Nations (A/AC.105/637).

B. Centres for space science and technology education: regional cooperation in basic space science

17. Regional facilities supporting the use of existing institutes, organizations and infrastructure to establish regional educational and training facilities are highly important for the education of future scientists.*

18. The Workshop strongly recommended that existing regional cooperative structures (such as the Organization of African Unity and the Organization of American States) should be used to organize, stimulate and find support for regionally driven activities, such as the following:

(a) Encouraging the development of basic space science such as astronomy and geoplanetary research through mutual cooperation;

(b) Training and education in the use of modern techniques and instrumentation through the organization of courses and fellowships for the training of young scientists;

(c) Coordination in the development of the instrumentation needed for the efficient utilization of available regional facilities;

(d) Pursuit of research in basic space science and the necessary associated education;

(e) Dissemination of astronomical information on a regional basis;

(f) Regional exchanges of established scientists and educators.

C. Basic space science in Africa

19. The African participants in the Workshop, recognizing the leading role that basic space science can play in general intellectual, cultural and scientific development, as well as in the transfer of technology to Africa, and wishing to promote international cooperation and coordination between basic space scientists in Africa and elsewhere, formed a working group on basic space science in Africa. The long-term objective of the working group is to make possible the creation of an African institute for space science. To that end, the working group established the following strategic objectives to be immediately implemented in the region:

(a) Creating and maintaining a database of all African scientists involved or interested in basic space science in Africa;

(b) Promoting education in basic space science at all levels in African communities;

(c) Organizing regional conferences and training workshops;

(d) Identifying resource needs and coordinating efforts to address those needs;

(e) Promoting the participation of African space scientists in international endeavours;

(f) Promoting the active participation of African countries in space exploration by pursuing possibilities for collaboration in future space missions;

---

*In that connection, the United Nations initiative aimed at the establishment of centres for space science and technology education in the five major economic regions is significant (A/AC.105/625).

(g) Establishing a programme, beginning in October 1996, to develop well-trained faculty members in science and engineering by initiating a grant system to finance the required studies;

(h) Working toward the creation of science centres to disseminate information about basic space science in African countries.

20. The working group will meet annually to review progress and to formulate its objectives and strategy. It will communicate with its members through a quarterly newsletter, which will be a forum for information exchange as well as a medium for dissemination of educational materials in basic space science.

D. International network of astronomical observatories

21. The participants in the Workshop recognized that:

(a) The study and discovery of Near-Earth Objects[1] are important activities requiring the participation of observers all over the world;

(b) Newly created observation facilities, even though they may be of limited size, can be of great importance for such work;

(c) The need for efficient coordination of studies made at widely different locations on the surface of the Earth, and from space, will give a powerful impetus to both intellectual development and international communication;

(d) The need for studies can justify support for activities associated with the creation of new facilities in places where they do not yet exist, and can thus generate scientific developments that will continue to enhance the participation of developing countries in basic space science.

22. In view of the above, the Workshop recommended that the creation of an international network of observatories needed for such observations should be supported.

E. Continuation of the workshops on basic space science

23. The participants recognized the importance of the accomplishments of the five previous United Nations/ESA workshops on basic space science in the developing countries. Those workshops were of particular importance for regular contacts at the scientific level between participating countries, as no other forum allows scientists from developing countries to interact in such an effective manner.

24. The participants also considered that the mutual exchange of experiences between those in the early phases of participation in basic space science represents an essential part of the accelerated development required, and that an interruption of the series of United Nations/European Space Agency workshops at this stage would create a setback for worldwide collaboration in basic space science.

25. The participants considered that establishing a process of communication between the nascent communities in basic space science and their Governments is an important part of participation in basic space science, and that the educational and purely scientific endeavours identified have been a strong stimulus for enhanced participation in space-related scientific activities.

26. The participants strongly recommended that the United Nations should exert its best efforts to ensure that the United Nations/European Space Agency workshops on basic space science continue in the years to come - at least through one more cycle - and that the chosen venues remain such that the benefits of the workshops are optimally oriented toward young scientists in the various geographical regions.

27. Since offers to host future workshops have already been received, it was considered highly desirable to ensure that the rotation of workshops among the geographical regions should be maintained.

28. The participants stressed that the free flow of ideas, which is becoming ever more important in the modern communications society, is an essential part of successful participation in basic space science.

II. FOLLOW-UP PROJECTS OF THE UNITED NATIONS/EUROPEAN SPACE AGENCY WORKSHOPS ON BASIC SPACE SCIENCE HELD FROM 1991 TO 1996

A. Asia and the Pacific: astronomical telescope facility in Sri Lanka

29. The Arthur C. Clarke Centre for Modern Technologies[2] was established in 1984 with the objective of introducing and accelerating the development of modern technologies in the fields of computers, communications, space science, robotics and energy. The technical work commenced in 1987, and the Centre has been progressing rapidly since then. The Centre has a technical staff capable of developing microprocessor-based electronics and communications equipment, and provided with well-equipped laboratories for research and development work in the above-mentioned fields. The activities in space technology began in the late 1980s with only the satellite information receiving facility.

30. As a result of the First United Nations/European Space Agency Workshop on Basic Science, held at Bangalore, India, in 1991 and organized by the Office for Outer Space Affairs, the United Nations recommended and supported the establishment of a telescope facility in Sri Lanka. That Workshop and subsequent discussions held with the Government of Japan also led to a donation to Sri Lanka, under the Japanese Cultural Grant Aid Programme, of a 45-centimetre reflecting telescope. In 1992, a representative of the Government of Japan visited Sri Lanka and held discussions with many institutions concerning the site for the installation. Considering the heavy expenditure involved, it was decided to install the telescope at the Arthur C. Clarke Centre for the following reasons:

(a) A new four-story building was being constructed at the Centre, and the top floor could be modified to host the telescope facility;

(b) The Centre has the capability of handling the repair and maintenance of the fully automated, electronically equipped telescope facility.

31. The telescope facility at the Centre was inaugurated at the Fifth United Nations/European Space Agency Workshop on Basic Space Science, held at Colombo from 11 to 14 January 1996 (A/AC.105/640).

32. Astronomical activities at the Centre are currently handled by its Space Applications Division, set up in 1994 with government approval. The Space Applications Division operates and maintains the telescope facility at the Centre, and has introduced a few programmes to popularize astronomy in Sri Lanka.

33. The Space Applications Division has begun to maintain a database of amateur astronomy societies and astronomical societies in order to meet the needs of Sri Lankan schools for observation facilities. To promote education in astronomy, the Centre will be launching a weekend programme for science teachers in consultation with the Department of Education. The programme will be free of charge, the cost of the training being borne by the Centre. Live radio broadcasts of the programme to the rural community have been arranged, as the radio is still the most popular medium of communication in rural Sri Lanka.

34. Since January 1996, the Centre has been organizing observation programmes for science societies and scientific professional institutions in order to promote astronomy among professionals in Sri Lanka.

35. With assistance from international organizations such as the United Nations and the International Astronomical Union (IAU), the Centre is planning to conduct an undergraduate course in collaboration with universities in Sri Lanka. IAU has already agreed to support the Centre financially and to send a resource person to work on the proposed programme.

36. The Centre intends to launch an international programme in corporation with observatories in other countries, and also wishes to be engaged in NASA programmes as soon as the staff of the Centre obtain the necessary training through programmes already arranged.

37. The training programmes for scientists at the Centre have been finalized with the support of the Japan International Corporation Agency through the Bisei Observatory in Japan. Another training programme is being negotiated through the Overseas Development Administration of the United Kingdom for post-graduate studies in astronomy at a university in the United Kingdom. The Centre has carried out a site survey for a future project to set up a national observatory in Sri Lanka once astronomy becomes popular in the country.

B. South America: Galactic Emission Maps project in Colombia

38. At the Second United Nations/European Space Agency Workshop on Basic Space Science, held at San José, Costa Rica, and at Bogotá, Colombia, in 1992, it was stated that the Andean equatorial region offered a combination of geographical attributes, unavailable in other regions of the world, that had great scientific potential for a certain class of observations. Its equatorial latitude and the presence of high peaks (above 4,000 metres) opened up many scientific opportunities. Those characteristics make the region advantageous for observations of the galactic disk (in the radio part of the spectrum) and for observations requiring simultaneous access to both celestial hemispheres. Other classes of experiment, such as automated supernova searches, complement existing efforts at sites in the northern and southern hemispheres.

39. The need for an accurate determination of the diffuse radio and microwave emission from the galactic disk was highlighted by the limitations imposed on cosmic microwave background (CMB) data because of galactic foreground emission. The Galactic Emission Maps project involves international collaboration (Brazil, Colombia, Italy, Spain and United States) aimed at obtaining an absolute-calibrated multifrequency sky survey in the range 408 to 5,000 megahertz. A 5.5-metre parabolic reflector equipped with total power radiometers at 408, 1,465 and 2,300 megahertz and with a differential radiometer at 5,000 megahertz has been built and is being operated at selected sites to achieve maximum sky coverage. The first map at 408 megahertz taken from the equatorial site in Colombia has been presented, and the ways in which galactic contamination affect CMB data and correction methods are to be discussed.

40. The scientific opportunities offered by, and the feasibility of establishing, an astronomical observatory in Colombia[3] have been explored.

C. Central America: astronomical observatory in Honduras

41. In the early part of the 1990s, Honduras took the initiative to establish the first astronomical observatory in Central America. On the basis of a strategy of regional cooperation between Central American national universities and of contacts between astronomers and prestigious astronomical research centres at the international level, the first steps towards the establishment of the observatory were taken at the Second United Nations/European Space Agency Workshop on Basic Space Science. Since 1994, an astronomical observatory has been functioning at the *Universidad Nacional Autónoma de Honduras*[4] (the National Autonomous University of Honduras) at Tegucigalpa. This academic institution has been equipped with a 42-centimetre computerized telescope and other facilities, and is ready to begin a programme for training researchers and technicians from Central America. Several important cooperation agreements are being implemented to promote the development of basic space science in the region.

D. Western Asia: Kottamia Observatory in Egypt

42. In conjunction with the Fourth United Nations/European Space Agency Workshop on Basic Space Science, held at Cairo in 1994, it was decided to refurbish the telescope at the Kottamia Observatory in Egypt. The National Research Institute for Astrophysics and Geophysics (NRIAG) at Helwan and the Ministry of Scientific Research of Egypt entered into a contract financed by the Government of Egypt. The project included the design and manufacture of a new optical system for the 1.88-metre telescope tube. The mirror materials were made from schott zerodur to ensure superb optical quality in the temperature range for observations. In order to achieve a high-quality optical surface in all applicable positions of the telescope, a new support, or mirror cell, for the primary mirror will be necessary. A new 18-point support instead of the old nine-point support has been proposed, and will become part of the project. The new optics will be integrated into the nearly 30-year-old Kottamia telescope, and first light is expected in early 1997. In July 1995, the representatives of NRIAG accepted the results of tests of the blanc for the primary mirror at a factory in Germany. The mirror was still being ground and polished, resting on an 18-point support just as in the future telescope cell. The procedure was to take several months, first creating a surface of high quality and then gradually approximating the required spherical shape. Preliminary tests of the mirror shape showed excellent results, and the preliminary acceptance tests were to be carried out on schedule in 1996.

E. Contribution of Egypt to the United States/Russian Federation Mars mission scheduled for 2001

43. During the Fourth United Nations/European Space Agency Workshop on Basic Space Science, the possible participation of Egypt in a future Mars Rover Mission[5] was discussed. One suggestion was that Egypt participate in the Mission through the design, building and testing of a drill for obtaining subsurface samples.

44. TPS, a sponsor of the series of United Nations/European Space Agency workshops, is following up that suggestion. TPS representatives, together with Egyptian scientists, have begun organizing a study of the concept. They informed the Space Research Institute of the Russian Academy of Sciences about the idea, and the Institute, in turn, formally invited the Ministry of Scientific Research of Egypt to study the concept for potential use on the Russian Mars 2001 Mission. Such a study has already begun.

45. Inclusion of a sort of drilling mechanism in the payload of such a mission would assist scientists in the investigation of volatile organic materials and mineralogy. Twenty years ago, the Viking Mars lander was able to obtain samples from depths of up to 10 centimetres. Today, a drill with the capability of boring more than 1 metre would be essential to further research and investigation.

46. Egypt has expertise in drill development. A few years ago, as part of the archaeological exploration of the Pyramids, a sophisticated drilling system was developed to drill into a subsurface chamber and deploy a camera without allowing air into the chamber. The drill perforated the limestone to a depth of two metres without the use of lubricants or cooling fluids that might have contaminated the environment of the pit, and successfully collected six samples.

47. The above-mentioned experiment and other more common terrestrial applications suggest that the necessary technology base for drill development can be brought together in the Russian Mars 2001 Mission.

48. A study team of Egyptian scientists, collaborating with Russian Federation, United States and European scientists, has been established.

III. SELECTED PROJECTS

A. Oriental Robotic Telescope network

49. The objective of the Oriental Robotic Telescope (ORT) network is non-stop observations on variable stars with other networks of automated photometric telescopes. Complementary to the ORT network in longitude and latitude intervals are projects such as the Global Network of Astronomical Telescopes in the United States, the Chilean cordillera stations and the South African stations. Photometric telescopes will be dealt with initially and then extended to spectroscopy.

50. The data collected by each station will be automatically and simultaneously transmitted via the Internet or telecommunication satellites to all the scientific centres of the network, making common rapid data reductions possible.

51. From 12-year archives of meteorological satellites, it appeared that sites located at a latitude of between 15° and 35° north and a longitude of between 10° west and 110° east have high-quality astronomical conditions with a significant annual number of clear nights. Such sites involve countries from Morocco to the western deserts of China. In addition to their astronomical history, those countries are suitable because they have high mountains in semi-desert areas, resulting in a clear sky with low telluric absorption. The site selection will be completed by local astronomical tests, such as scintillation and seeing measurements.

52. The prediction of sky quality, together with local access facilities, ought to give a list of network stations not subject to the same air streams. The minimum number of network stations necessary to follow the variable stars each night without interruption is 10.

53. Many of the countries in question have had great astronomers in the past, but nowadays few of them carry out research in astrophysics or teach it. The *Institut des sciences de l'univers/Centre national de la recherche scientifique*, the *Observatoire de Haute-Provence* (OHP) and the *Observatoire Midi-Pyrénées* (OMP) have therefore proposed to collaborate in developing education in astronomy and astrophysics and in training students in the universities of those countries using the facilities of an astrophysical laboratory equipped with a telescope of 60 centimetres in diameter. The training of engineers and technicians in French observatories such as OHP and OMP has also been proposed.

54. The aim of such efforts is to accelerate the astrophysical development of the countries concerned with a view to ensuring their rapid scientific and technical participation in the ORT network. The reduction and interpretation of the scientific data would be jointly undertaken, and the scientific results would be shared.

55. Since the majority of astronomical objects are variable, and since several characteristic time scales of variations are often detected in the same object (in years, days, hours or less), the analysis of variabilities increases the knowledge of the physical processes operating in those objects.

56. The main scientific programmes concern:

(a) Stellar variability (i.e. asteroseismology) on, *inter alia*, T Tauri, Be and B, W CMa, δ Scuti, Ap- and Am-type stars, red giant and dwarf stars, planetary nebulae and post-novae;

(b) Planetology, involving the search for planets around stars and stellar occultations in the solar system, the analysis of planets and their satellites and other research.

57. Because of the rotation of the Earth, collaboration between networks of robotic telescopes devoted to such programmes may assist in resolving some important contemporary astrophysical problems in:

(a) Photometry: this technique measures the stellar flux variation at some wavelengths, and enhances knowledge of the evolution and internal structure of the stars;

(b) Spectroscopy: this technique, in its low-resolution modes, establishes the abundance of the chemical elements, and, in its high-resolution modes, is able to establish the physical parameters of stars and their dynamic behaviour;

(c) Interferometry: this technique, on radio, infrared or visible frequencies, establishes the diameter variations or the shape of stars, and even provides a detailed description of their external layers, with ejections of matter, among other measurements. The stellar neighbourhood can also be examined and planets discovered.

58. Since photometry is the simplest of the observational techniques, it is proposed to begin by following stellar variability in the UBVRI spectral ranges. The observations will be made with large-field Ritchey-Chrétien telescopes equipped with charge-coupled-device cameras.

59. During the First International Conference on Space and Astronomy, held at Amman in September 1994, an international committee to promote the ORT network was created, including members representing Egypt, France, Iraq, Jordan, Lebanon, Libyan Arab Jamahiriya, Morocco and Yemen. Discussions are under way with Algeria, Bahrain, Brunei, India, Indonesia, Iran (Islamic Republic of), Malaysia, Mauritania, Pakistan, Saudi Arabia and Tunisia.

60. Contacts must still be developed with China, Kuwait, Oman, Qatar, Syrian Arab Republic, Tajikistan, United Arab Emirates, Uzbekistan and other States that are interested in participating.

B. Pierre Auger project sponsored by the United Nations Educational, Scientific and Cultural Organization

61. An international group of 100 physicists and engineers based at the Fermi National Accelerator Laboratory, west of Chicago, Illinois, has begun to design the detector for the Pierre Auger Cosmic Ray Observatory[6] to study the highest-energy cosmic rays observed on Earth. Named after the French physicist who in 1938 first detected the air showers produced by high-energy cosmic rays, the Pierre Auger project will seek to identify the unknown source of the highest-energy cosmic rays that reach the atmosphere.

62. The design group receives support from the United Nations Educational, Scientific and Cultural Organization (UNESCO), Fermilab, the Grainger Foundation, the National Science Foundation, the Universities Research Association, Inc. and the University of Chicago.

63. The Pierre Auger project began a six-month workshop on 30 January 1995. During the workshop, a core group of about 10 scientists worked at Fermilab. The rest of the participants came to Fermilab for meetings, but worked mainly at their home institutions, communicating electronically in a "workshop without walls". On 30 July 1995, at the end of the workshop, the design was published in a book-length description of the cosmic ray detector of the project. The report explained the scientific motivation for the project, and presented a technical design, a site survey report and a cost estimate.

64. The design report serves as a basis for proposals for funding from participating States. Thus far, the Pierre Auger project involves participants from Argentina, Australia, Brazil, China, Egypt, France, Germany, Italy, Japan, Russian Federation, South Africa, Sweden, United Kingdom, United States and Viet Nam.

65. With funding secured, the Pierre Auger project will build and operate the detectors, two 2,500-square-kilometre arrays, one in the southern hemisphere (Argentina) and one in the northern (United States). The group hopes to be ready to observe the first high-energy cosmic-ray air showers of the new millennium.

66. The data management will be divided into three broad areas, involving the monitoring of data, real data and discrete data. High-quality data will be saved in the mass storage system. If enough funding becomes available, the project is expected to be completed by the turn of the century.

C. Education and research using small astronomical telescopes

67. Small telescopes (generally from 0.4 to 1 metre in diameter, but sometimes smaller or larger) are found in research observatories; in universities, where they are used for research and teaching at all levels; occasionally in schools; in public observatories or attached to planetariums and science centres; and often in the hands of individual amateur astronomers or clubs. Depending on its location, the telescope may be used for research by professional or amateur astronomers, or for the training of astronomers. In each case, the telescope may also be used to instruct and inspire students and the general public, thus contributing to the support and advancement of astronomy.

68. At the Fifth United Nations/European Space Agency Workshop, it was decided that an education and research curriculum for the use of small telescopes, especially in developing countries, should be developed. A paper prepared by India, entitled "Small telescopes in research and education", was distributed to all participants at the Sixth United Nations/European Space Agency Workshop. It concluded that: "(i) When a new astronomical facility is set up, it should be at a level consistent with the workshop facilities and infrastructure support available. The equipment should not overwhelm the user; (ii) For the initial training of manpower, cooperation should preferably be sought from countries which are culturally akin to the host country; (iii) Attempts should be made to integrate astronomical facilities with the teaching programme; (iv) For best results, observational programmes should be chosen so as to form a part of international campaigns." The paper provided a focus for discussion at an informal two-hour plenary session at the Sixth Workshop.

69. The conclusions presented in the paper submitted by India were warmly received by the participants. A few other significant observations and recommendations were made during the discussion, including the following:

(a) Because of the varied uses of small telescopes, the needs of students, teachers, amateur astronomers and the general public should be taken into account in drawing up the relevant curricula;

(b) Future United Nations/European Space Agency workshops should include more time for discussion and practical activities;

(c) The telescope should be simple, well-instrumented and appropriate to the local infrastructure and expertise;

(d) Internet connections are important for many aspects of the use of small telescopes, for example, in resorting to e-mail for international communication and collaboration, and in accessing remote telescopes and databases.

70. It was also recommended that:

(a) The current initiative should be pursued by a working group consisting of both small telescope experts and users;

(b) The working group should compile a practical guidebook to the use of small telescopes, on the basis of both existing and new material. The guidebook could be edited and distributed by the United Nations;

(c) A future United Nations/European Space Agency workshop should be held at an astronomical observatory with a small telescope, placing strong emphasis in the agenda on the practical aspects of teaching and research with such a telescope;

(d) Users of such telescopes should have a strong input to the above-mentioned agenda;

(e) Assistance should be sought from knowledgeable outside organizations (such as IAU) and individuals.

71. Participants emphasized that, especially in developing countries, the enhancement of science education and literacy (both in schools and among the general public) could facilitate further progress in basic space science and astronomy. Conversely, basic space science and astronomy could promote public awareness, understanding and appreciation of science, and attract young people to the study of science and technology.

D. Developing astronomy and space science worldwide

72. The United Nations/European Space Agency workshops on basic space science represent one part of the efforts now being made by several international agencies and through bilateral cooperation between specific institutions in developing and developed countries to assist astronomers in developing countries. It is particularly valuable that the workshops have been held in each of the major economic regions of the world, since this will stimulate intra-regional cooperation. During the Sixth United Nations/European Space Agency Workshop, for example, participants saw important steps towards such regional cooperation being taken by astronomers from several African countries, and some tentative ones taken by participants from the region of Asia and the Pacific. Astronomers from Central America have provided a very good example of how small, neighbouring countries can work together usefully. Their cooperation was undoubtedly stimulated partly by the Second United Nations/European Space Agency Workshop. Sometimes, within a region, a developed and a developing country may be neighbours, and a useful cooperative relationship can be established with a minimum of formalities. A good example of this is the close working relationship between astronomers in Morocco and those at the University of Nice, in France. In other regions, although all the countries may be developing ones, some are clearly more advanced in certain respects than others. In astronomical matters, China and India are at a quite different level from most other developing countries in Asia. Regional cooperation between the astronomers of Asia has a high potential for the development of astronomy in some of the smaller countries.

73. In addition to organizations such as European Space Agency and TPS, which have cooperated directly with the United Nations in the organization of the basic space science workshops, other organizations have concerned themselves with assisting astronomers in developing countries. UNESCO is currently encouraging regional cooperation among the southern States members of the Commonwealth of Independent States. About 10 years ago, IAU formed a Working Group for the Worldwide Development of Astronomy, reflecting its growing concern for astronomers in developing countries since the end of the Second World War. The IAU Working Group has been particularly interested in astronomy in Central America, north Africa and Viet Nam. Although IAU can provide only limited financial resources, it can extend assistance through its international schools for young astronomers and the newly instituted Teaching for Astronomy Development programme. By such means, astronomers can be brought into the countries concerned in order to assist in the establishment of teaching and research capabilities.

74. Perhaps the most important effort that the United Nations, IAU and other organizations make is to provide isolated astronomers with the personal contacts that they need. Modern means of communication, such as e-mail, have desensitized many individuals in developed countries to the problems that astronomers in developing countries face. To the typical astronomer in a developed country, e-mail and the associated possibilities of electronic publication are the cheap panacea to all problems of communication. It is exceedingly difficult to convince such an individual that for an astronomer in a developing country, e-mail,

if available at all, is often intermittent and unreliable. Electronic journals, even if they should turn out to be cheaper to subscribe to, are beyond what many astronomers can hope to use in the foreseeable future. Some individuals have e-mail, but not in a location that they can visit every day. E-mail messages are sometimes received from astronomers who give a return electronic address which never appears to be operating. Organizations like the United Nations and IAU can at least bring these problems to light; perhaps they could even bring some influence to bear on their solution; but the most important help will come from individuals and specific institutions.

Notes

[1]"Near-Earth Objects: the United Nations International Conference", *Annals of the New York Academy of Sciences*, vol. 850, 1996.

[2]*Fundamental Studies and Future of Science* (Cardiff, University College Cardiff Press, 1984).

[3]*Science and Technology for Central America: Plans and Strategies* (San Salvador, University of El Salvador, 1995).

[4]"An astronomical observatory for Central America: a realistic way of strengthening basic space science in developing countries", *American Institute of Physics Conference Proceedings*, vol. 320, 1994, pp. 13-22.

[5]"The Marskhod Egyptian Drill Project", in *Developing Astronomy and Space Science Worldwide* (United Nations, forthcoming).

[6]"Cosmic ray mysteries", *Physics World*, vol. 9, 1996, pp. 47-52.

Bibliography

General

United Nations. Office for Outer Space Affairs. Planetarium - a challenge for educators; a guidebook published by the United Nations for International Space Year. 1992.

United Nations. Office for Outer Space Affairs. Developing astronomy and space science worldwide. An assessment of the achievements of the series of United Nations/European Space Agency workshops on basic space science in the period 1991 to 1996.
Forthcoming.

First workshop

American Institute of Physics. Basic space science. Proceedings of the first United Nations/European Space Agency workshop on basic space science. New York, 1992. (American Institute of Physics Conference Proceedings Volume 245)

United Nations Committee on the Peaceful Uses of Outer Space. Report on the first United Nations/European Space Agency workshop on basic space science, held at Bangalore, India, 30 April-3 May 1991. (A/AC.105/489)

Second workshop

Basic space science. Proceedings of the second United Nations/European Space Agency workshop on basic space science (Colombia). *Astrophysics and space sciences* 214:1-2, April 1994.

Basic space science. Proceedings of the second United Nations/European Space Agency workshop on basic space science (Costa Rica). *Earth, moon and planets* 63:2, November 1993.

United Nations Committee on the Peaceful Uses of Outer Space. Report on the second United Nations/European Space Agency workshop on basic space science, held at San José, Costa Rica, and Santa Fe de Bogotá, Colombia, 2-13 November 1992. (A/AC.105/530)

Third workshop

American Institute of Physics. Basic space science. Proceedings of the third United Nations/European Space Agency workshop on basic space science. New York, 1994. (American Institute of Physics Conference Proceedings Volume 320)

United Nations Committee on the Peaceful Uses of Outer Space. Report on the third United Nations/European Space Agency workshop on basic space science, held at Lagos, Nigeria, 18-22 October 1993. (A/AC.105/560/Add.1)

Fourth workshop

Basic space science. Proceedings of the fourth United Nations/European Space Agency workshop on basic space science (Egypt). *Astrophysics and space sciences* 228:1-2, June 1995.

Basic space science. Proceedings of the fourth United Nations/European Space Agency workshop on basic space science. *Earth, moon and planets* 70:1-3, 1995.

United Nations Committee on the Peaceful Uses of Outer Space. Report on the fourth United Nations/European Space Agency workshop on basic space science, held at Cairo, Egypt, 27 June-1 July 1994. (A/AC.105/580)

Fifth workshop

United Nations Committee on the Peaceful Uses of Outer Space. Report on the fifth United Nations/European Space Agency workshop on basic space science, held at Colombo, Sri Lanka, 11-14 January 1996. (A/AC.105/640)